Twenty years of measuring marine protected area (MPA) effectiveness in Channel Islands National Park, California: a model for Baja to Bering.

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Introduction

The eight islands off the southern California coast have long been the focus of conservation efforts. In 1938, President Roosevelt proclaimed Channel Islands National Monument, comprising the islands of Anacapa and Santa Barbara. The waters and submerged lands surrounding the two islands out to one nautical mile were added to the monument in 1949. These actions initiated the current era of special attention afforded to these islands and adjacent waters. Thirty years later the National Park Service, expressing concern about declining sea life in the monument, restricted fishing and kelp cutting to half of the monument's waters. This action created two fully-protected reserves: one on the east side of Santa Barbara Island (~1,000 ha) and one on the north side of Anacapa Island (~2,200 ha) that were in place for nearly 10 years. The State of California successfully challenged the authority of the Federal government to regulate take of living marine resources in the monument in 1978 (U. S. Supreme Court, 436 US 32). That decision extinguished the Federal reserves. California replaced them the same year with state ecological reserves, which allowed fishing and kelp cutting, except in a 13 ha natural area along 2.5 km of the north shore of East Anacapa Island to a depth of 18 m.

In the 1970s, the islands were the last best place to go fishing in southern California, but technology (e.g., faster boats, electronic global navigation) eventually overcame the defacto isolation that had prevented overfishing, and new conservation strategies were needed. A new state and federal joint adaptive management scheme was initiated in 1980. The U. S. Congress expanded the national monument by adding the remaining three northern islands and 50,600 ha of the surrounding submerged lands and waters to establish Channel Islands National Park. Later the same year, President Carter declared the waters within 11 km of the five park islands to be a national marine sanctuary. These federal actions acknowledged the authority of California to manage living marine resources in park and sanctuary waters, and charged federal agencies to monitor resource conditions and to make recommendations to better protect these resources. This paper describes the outcomes of a 20-year performance evaluation monitoring program and consequent measures taken to improve conservation in the next round of adaptive management.

Site Description

The California Channel Islands lie 20-110 km off the southern California coast between Santa Barbara and San Diego. Some the world's largest kelp forests surround the islands. The region enjoys a mild Mediterranean climate with warm, dry summers and cool, moist winters. These islands and surrounding waters bridge two biogeographical provinces, the warm-temperate Californian and cool-temperate Oregonian, with a third transition zone between them (Hedgepeth, 1957; Briggs, 1974), which include the biologic diversity of 1,500 km of the North American west coast. Nearly 1,000 species of marine fish, macroinvertebrates, and algae occur in extensive kelp forests of *Macrocystis pyrifera* surrounding the islands (Davis *et al*., 1997).

The confluence of ocean currents and a persistent upwelling zone off nearby Point Conception bring nutrients up from the dark seabed into well-lighted surface waters, providing the basis for exceptionally high productivity. Northern elephant seals (*Mirounga angustirostris*), sea lions (*Zalophus* spp.), fur seals (*Callorhinus* spp.), harbor seals (*Phoca* sp.), Cassin's auklets (*Ptychoramphus aleuticus*), Xantus' murrelets (*Endomychura hypolencia*), cormorants (*Phalacrocorax* spp.), pigeon guillemots (*Cepphus columba*), petrels (*Oceanodroma* spp.), gulls (*Larus* spp.), and brown pelicans (*Pelicanus occidentalis*) breed and raise their young on these islands, where they are safe from disturbance and near abundant food along the 240 km shoreline of sand beaches, rocky tide pools, and shear cliffs that ring the islands. Twenty-six kinds of cetaceans occur around the islands, including pacific whitesided dolphins (*Lagenorhynchus obliquidens*), humpback whales (*Megaptera novaengliae*), Orcas (*Orcinus orca*), and blue whales (*Balaenoptera musculus*).

Today, nearly 18 million people live within 300 km of the park and sanctuary. These people bring worldwide demands and cultural values for coastal resources from more than 170 human cultures. The ocean waters that separate the islands from the mainland limit public access to the islands, yet each year scuba divers make 100,000 explorations of island reefs and kelp forests. Boaters find shelter in nearly 100 secluded anchorages in the park.

Pollution and other human activities in nearby metropolitan and industrial developments altered many interdependent elements of coastal ecosystems. Park waters once yielded many thousands of tons of fish, shellfish, and kelp annually to commercial and recreational fishers, producing nearly 20% of California's nearshore landings from only 3% of the state's coastal waters. Recent collapses of fishery-targeted populations revealed that managed traditionally, neither the fisheries nor the populations were sustainable. Normal dynamics of these systems, exemplified by El Niño and La Niña events, masked human influences and made management uncertain, at best.

Conservation Goals and Management Objectives

National parks in the United States were established to provide for people's enjoyment of the parks now and in the future by conserving unimpaired scenery, natural and historic objects, and biodiversity in parks. National marine sanctuaries have a similar multiple-use purpose to coordinate compatible activities. Neither designation prohibits fishing. These conservation strategies assumed that protecting habitat alone would assure sustainable fisheries, an assumption tested by monitoring and evaluating the effects of fishing on ecosystems and selected populations.

The Channel Islands ecological setting, including biological resources (populations and communities), environmental forces (climate and ocean currents), land forms (islands and ocean basins), and the park's legal purposes to conserve the integrity, stability and beauty of the park combined to determine the function–and thereby the structure–of the park's stewardship program. Major issues that focused this program included:

- unsustainable fishing, destructive grazing, and disturbances by visitors;
- habitat fragmentation, including loss of nearby mainland habitat and island erosion;
- air and water pollution and loss of fog-drip precipitation; and
- invasive alien species, such as the seaweeds *Undaria pinnatifida, Sargassum muticum*, and *Caulerpa taxifolia*,

Monitoring Program Goals

The National Park Service used a four-step process to institute a 'vital signs' monitoring program to inform, guide, and evaluate stewardship of the park (Davis 1993, 2004). The cornerstone of the park's stewardship program is a 'vital signs' monitoring program that seeks to:

1) determine present and future ecosystem integrity, a multidimensional property of ecological systems that indicates the nature of their organization—structure composition, and processes (Parrish et al., 2003);
2) establish empirically normal limits of variation;
3) provide early diagnosis of abnormal conditions; and
4) identify potential agents of abnormal change.

The National Park Service, collaborating with the California Department of Fish & Game and Channel Islands National Marine Sanctuary, began monitoring ocean resources in Channel Islands National Park in 1981 to augment traditional fishery landings data collected since 1916 in California (Davis 1989, Davis et al. 1994, Leet, et al. 2001). Fishery-independent measurements of fish, invertebrate, and algal demographics (density, distribution, and size structure) for 70 taxa in the East Anacapa Natural Area and in the adjacent and distant fished areas of the park and sanctuary revealed dramatic differences over 20 years (Davis et al. 1997).

<u>Status and Trends of Performance Measures 1982-2004</u>

Unintended ecological consequences of human actions cascaded for decades through ocean and coastal ecosystems in the park and sanctuary. In fished areas, abalone (*Haliotis rufescens, H. corrugata, and H. sorenseni*) densities declined from 2,000 ha^{-1} to < 12 ha^{-1} (the lower limit of detectability) and juvenile recruitment virtually ceased, while in the East Anacapa Island Reserve densities remained low and stable, at >200 ha^{-1} (Davis et al. 1992, Davis 1995). *H. sorenseni* was listed as an endangered species in 2001 (Hobday, et al. 2001). California closed all abalone fisheries in southern California in 1997 to protect remnant brood stocks (Karpov et al. 2000). Exploited large red sea urchins[1], *Strongylocentrotus franciscanus*, similarly declined in fished areas from densities of 12,000 ha^{-1} in the early 1980s to < 2,000 ha^{-1} by the 1990s, while they remained high (12,000-15,000 ha^{-1}) in the East Anacapa Reserve. Other fishery-targeted species, such as warty sea cucumbers, *Parastichopus parvimensis,* spiny lobster, *Panulirus interruptus,* and several fishes, e.g., California sheephead (*Semicossyphus pulcher*), and rockfish (*Sebastes* spp.), showed similar patterns of extreme depletion in fished areas while remaining stable at high levels in the reserve (Larson 2000, Lafferty and Kushner 2000, Schroeter et al. 2001, PISCO 2002).

Unexploited species showed very different patterns of population dynamics during this same period. Within the reserve, small purple sea urchins, *S. purpuratus*, remained at low densities (1,000-5,000 ha^{-1}). While in fished areas purple sea urchins were ten times more abundant than in the reserve and they fluctuated widely from 50,000 ha^{-1} to 400,000 ha^{-1}, controlled by lack of food and disease, rather than by predation from spiny lobsters and California sheephead and competition with other sea urchins and abalone as they were in the reserve (Lafferty and Kushner 2000). Densities of garibaldi (*Hypsipops rubicunda*), the protected state marine fish, remained at the same in both reserve and fished areas throughout the two decade period. High densities of purple sea urchins in fished areas overgrazed the giant kelp, *Macrocystis pyrifera*, reducing nearly 80% of the kelp forest in the park to 'urchin barrens' for most of the period.

Kelp forests in the small reserve at East Anacapa Island retained their resilience throughout the study period. They recovered quickly (within a year) from major disturbances associated with ENSO/El Niño events in 1982-83, 1987-88, 1992-93, and 1997-98. Outside of the reserve, these events reduced kelp canopy and produced pulses of drift kelp, followed by increased spatial dominance of purple sea urchins, brittle sea stars *Ophiothrix* sp., and small sea cucumbers, *Cucumaria* sp. in areas formally dominated by giant kelp. These different responses to disturbance appeared to be related to changes in community structure and subsequent changes in biological interactions (competition and predation), since all other environmental factors, e.g., sea temperatures and pollution, were the same inside and outside the reserve.

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[1] >105 mm test diameter

Frequent and extensive analysis and synthesis of monitoring data also facilitated discovery of new features and characteristics of park ecosystems. Outbreaks of fatal new diseases, such as withering syndrome in black abalone, *Haliotis cracherodii*, were previously unknown, in part because no rigorous ecological monitoring took place before the 'vital signs' program. Monitoring revealed not only that black abalone populations collapsed in the park, but also provided a regional geographic and multi-year temporal description of the spread of catastrophic mortality (Richards and Davis 1993). Monitoring characterized population size structure of surviving abalone, showing persistence of large individuals at some sites but not at others. This information exonerated fishing (that took only large abalone) as a proximal cause of the population collapses at some islands, but implicated fishing as a contributing stress at others. Monitoring also showed that adult black abalone populations ceased to reproduce successfully when densities fell below 50% of their original values. These quantitative descriptions directed subsequent research to examine potential infectious agents, rather than toxic pollutants or poaching and other human activities, and led to the discovery of a new species of pathogen (Friedman *et al.,* 1995). 'Vital signs' monitoring provided an early warning with sufficient information to protect disease-resistant individuals from fishery harvest and thereby help ensure survival of another generation.

Conclusions

MPA stewards need early warnings of conservation issues and effective measures of conservation efficacy to avoid irreversible losses of natural resources and economic opportunities. Twenty years of monitoring the environmental equivalent of medical vital signs at the California Channel Islands proved to be the quickest, surest, and cheapest way to evaluate marine protected area performance. The Channel Islands National Park 'vital signs' program has endured more than 20 years because it proved to be a cost-effective way to reduce uncertainty and to increase success of conservation efforts. The program reduced human conflicts and provided early warnings of unsustainable conservation practices. The early warnings gave resource managers, the public, and politicians time to respond, before remedial actions became too expensive or impossible to enact.

Information from this monitoring gave people confidence that changes in management policies and practices were needed. 'Vital signs' information guided ecological restoration by revealing the most successful strategies with timely information otherwise unavailable, e.g., eradication of feral rabbits, rats, and pigs. Monitoring information encouraged persistence by documenting partial success in meeting milestones and by estimating time and costs required for complete eradication. The information generated by this monitoring program also significantly increased confidence in management decisions and reduced the costs of resolving serious threats to the park's ecological integrity, such as overfishing.

Early warnings of pollution and unsustainable fishing helped avoid species extinction. Understanding the relative effects of pollution and fishing helped in the design of a network of marine reserves to restore depleted resources and support surrounding fisheries. In the latter 20th Century, many fisheries were managed and evaluated largely on the basis of fishery-dependent landings data that did not accurately reflect changes in fished populations (Schroeder *et al*., 2001). Fishery-independent monitoring provided essential corroborative information for fishery managers (Botsford *et al.,* 1997). Before monitoring data were available, ambiguous fishery landings data obscured the catastrophic serial depletion of five species of abalone (*Haliotis* spp.) and a sea urchin (*Strongylocentrotus franciscanus*) that had supported a commercial diving fleet in southern California (Dugan and Davis, 1993; State of California, 1995; Davis, 1998). As a result, take from fishing exhausted abalone populations before fishery management policies could be changed, and drove at least one species to the verge of extinction, *Haliotis sorenseni*, as evidenced by its listing as the first endangered marine invertebrate in the United States (Davis *et al.,* 1996, 1998; Davis, 2000; Hobday *et al.,* 2001). Early warnings of population collapses and ecosystem shifts that were generated by 'vital signs' monitoring prompted changes in resource management policy and strategy. These changes included explorations of new placed-based conservation paradigms, i.e., marine reserves, by the State legislature in a Marine Life Protection Act (Chap. 10.5 California Fish and Game Code, Sections 2850 and 2863) and by the State Fish and Game Commission in establishment of a large network of marine reserves in park waters (PISCO, 2002; Davis, in press).

Political systems are frequently frozen into inaction by uncertainty (Wurman, 1990). Reliable fishery independent data from 'vital signs' monitoring allowed political processes to work by reducing uncertainty regarding abalone population status, for example. Abalone population status could only be inferred from declining fishery landings, and those trends were persistently contested by fishing interests. Only after 'vital signs' monitoring data confirmed imminent abalone population collapses did the California Fish and Game Commission and State Legislature eventually close five abalone fisheries to prevent loss of critical brood stock, to facilitate recovery, and to reduce the costs of rebuilding depleted populations statewide. 'Vital signs' methodologies were also used to test a variety of different abalone population restoration techniques at the California Channel Islands (Davis, 1995, 2000; Davis and Haaker, 1995).

Public agencies and local communities responded to these undesirable changes in ocean resource conditions by searching for new approaches to stewardship. In 1998, a group of recreational anglers, calling themselves the Channel Islands Marine Resources Restoration Committee, and the National Park Service requested that the California Fish & Game Commission establish a network of marine reserves (no-take zones) in the park that constituted no less than 20% of the park's waters to restore the integrity of park ecosystems and to begin rebuilding depleted populations. In 1999, the California Legislature passed the Marine Life Protection Act (Chapter 10.5 of the California Fish and Game Code, Sections 2850 to 2863) to improve the array of Marine Protected Areas (MPAs) existing in California waters, and to protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and because such areas may help rebuild depleted fisheries. The California Department of Fish and Game was charged with implementing the provisions of the Marine Life Protection Act.

Channel Islands National Marine Sanctuary established a community-based advisory council in 1998. Its purpose was to provide advice on protecting resources, identifying critical issues, research objectives, and educational opportunities, and to assist in developing an informed constituency to increase awareness and understanding of the purpose and value of the sanctuary. The sanctuary manager proposed to the California Fish & Game Commission that this Advisory Council be used to respond to the request for marine reserves at the Channel Islands and to establish a process for considering specific reserves. The Commission accepted, and charged the Department of Fish & Game with co-chairing a Marine Ecological Reserve Working Group of shareholders with the sanctuary manager to explore marine reserves at the Channel Islands.

A marine reserve network was established in 2003, beginning the next round of adaptive management. The 10 reserves range in size from 477 ha to 10,974 ha (eight were greater than 3,500 ha, likely a minimum viable size for this ecosystem), and totaled 45,088 ha. They were well distributed, with three or four reserves in each of the park's three biogeographic regions. With regard to habitats, depths ranged from shore to 550 m, and included hard and soft substrates, with adequate examples of kelp forests, sea grass beds, submarine canyons, and adjacent wildlife rookeries. The network fell short of the scientifically recommended minimums of 71,192-118,652 ha needed to meet the biodiversity and fisheries goals, but certainly provided an opportunity to test the design criteria and efficacy of reserves to improve conservation at the California Channel Islands.

Discussion

Typical of many marine protected areas, stewardship of Channel Islands National Park involves extensive partnerships, and must address issues of habitat fragmentation, invasive species, unsustainable uses, and altered air, water and soil. Sustained time-series data at landscape scales produced by a 'vital signs' monitoring program permited resolution of complex environmental issues too difficult to address with typical ecological studies focused on meter-square plots for one or two seasons (Likens *et al.,* 1977; Tilman, 1989; Halvorson and Davis, 1996; Baskin, 1997). Separating effects of El Niño events, pollution, and fishing on coastal ecosystems at the Channel Islands required regional (100s km) analysis over several decades. This kind of analysis was needed to achieve the levels of certainty required to guide meaningful political actions, and to avoid irreversible resource damage while sustaining economic development and exploitation of fishery resources. Monitoring data also allowed research statisticians to explore previously unavailable real-world information they needed to develop new analytical methodologies.

The goal-setting, monitoring, and adjustment process produced useful outcomes and provided several important lessons. Taken in the largest sense, this was an excellent example of large-scale adaptive environmental management. After exhausting numerous traditional fishery management strategies to sustain resources and fishing opportunities over several decades, public agencies and local communities changed strategies. Science-based monitoring and research programs informed the decision process and continue to guide the new effort.

Aldo Leopold’s land ethic obliges people to honor ecological processes. That ethic pertains equally well to the sea. This ethic also obliges people to honor the process in social contracts: to ensure the steps we take toward our shared goals don’t so damage human relationships that we fail to reach our goals. As stewards of the sea, we enter into a covenant with one another and with the as yet unborn millions who will follow us. This generation is obligated to leave a legacy of hope and of opportunity for those who follow. The Channel Islands reserve network is a pioneering effort. It is a hopeful situation because community-supported decisions were made to begin restoration and to explore a new social contract. If successful, this generation of people will have preserved options to enjoy the sea that the next generation very nearly lost forever.

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